Evaluating the Impact of New Technologies Using Simulation: The Case for Mining Software Repositories

David M. Raffo, Ph.D., Portland State University
Tim Menzies, Ph.D., Portland State University

Agenda

- Motivation
- Learned Defect Detectors Highlights
- Process Simulation Highlights
- Model Overview
- Three Scenarios and Results
- Conclusions

Motivation

- Good new technologies are wasted
  - unless there is a compelling business case to use them
- Without such a case:
  - Managers not convinced
  - No reallocation of scarce resources
- Good technology: data mining defect detectors
  - increased PDs (probability of detection)
  - Lower PFs (probability of false alarm)
  - Lower inspection effort (more time for other, more specialized methods
- This talk:
  - The business case
  - Developed via process simulation

Things to Point Out…

- Synergistic research of multiple projects sponsored by NASA
- Analysis assessing the potential impact of a new tool NASA has been investing in
- Identifying new and creative ways that the tool can be applied to benefit NASA
- Detailed level of analysis
- “Field of Dreams” message for providing data. If you provide it, useful results will come.

Data mining defect detectors

- Data miners learn detect detectors from static code measures (McCabe and Halstead)at the module level.
  - Not perfect: widely deprecated (Shepherd, Fenton, and others)
  - Adequate as partial indicators (but watch that false alarm rate)

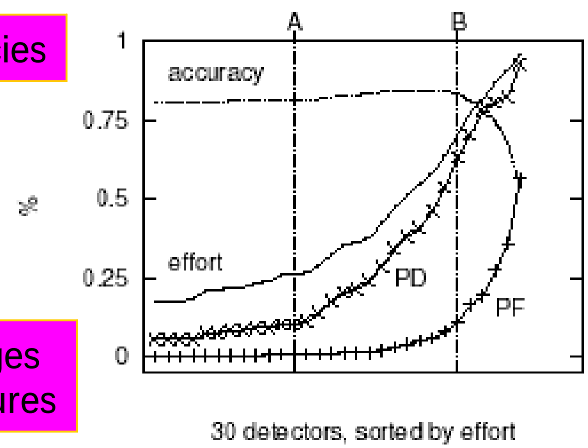
has defect

	No	Yes
detector silent	A	B
detector triggered	C	D

accuracy= (a+d)/(a+b+c+d)
pd = detection (or recall)
= d/(b+d)
pf = false alarms = c/(a+c)
prec = d/(c+d)
Effort = (C.loc + D.loc)/ (ABCD.loc)

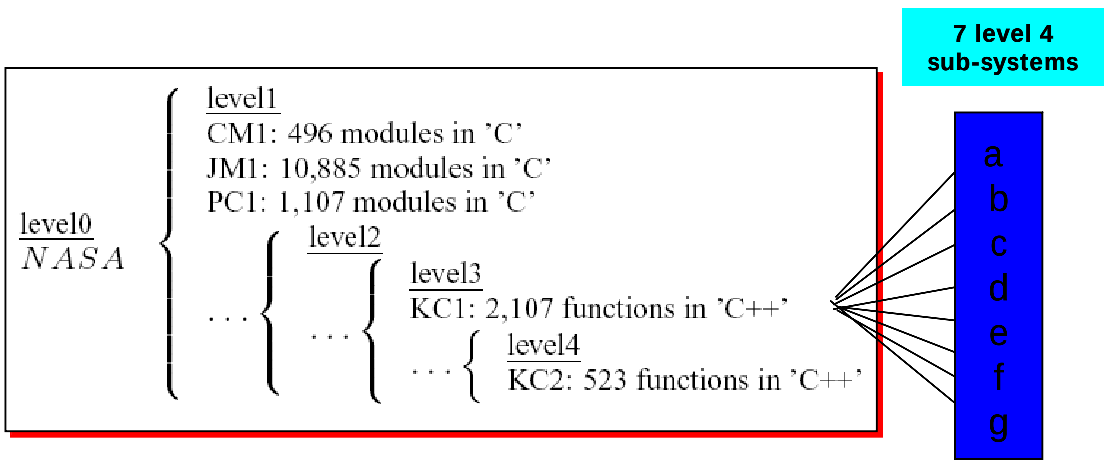
Stable accuracies

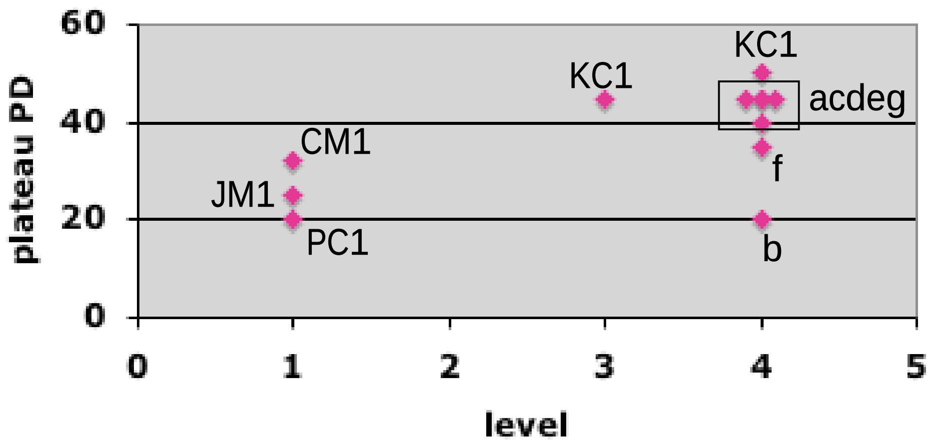
Massive changes in other measures

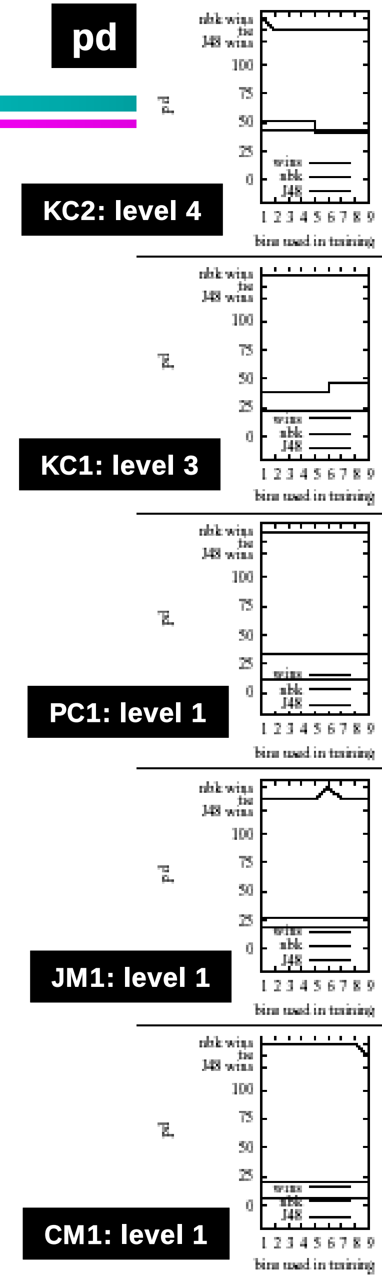


Results

- NBK will suffice (in 85% cases NBK same or better than J48)
- Early plateaus (50-200 examples are enough)
- Not shown: low PFs
- Stratification improves PD?







- Suggestive, not conclusive evidence for "stratification improves PD"

But, so what?

Is any of the above useful?

Introducing - Process Simulation

- One area that can help companies improve their processes is ***Process Simulation***.
- Process Simulation supports organizations to address
  - Strategic management
  - Process Planning
  - Control and operational management
  - Technology adoption
  - Understanding
  - Training and learning
  - Quantitative process management and other CMMI-Based Process Improvement

Features of Process Simulation and PTAM

- **Based on extensive research**.
- **Graphical user interface** and models software processes
- **Utilizes SEI methods** to define SW Processes
- **Integrates metrics** related to cost, quality, and schedule into understandable performance picture.
- **Predicts project-level impacts** of process improvements in terms of cost, quality and cycle time
- **Support business case analysis** of process decisions - ROI, NPV and quantitatively assessing risk.
- **Designed for Rapid Deployment**

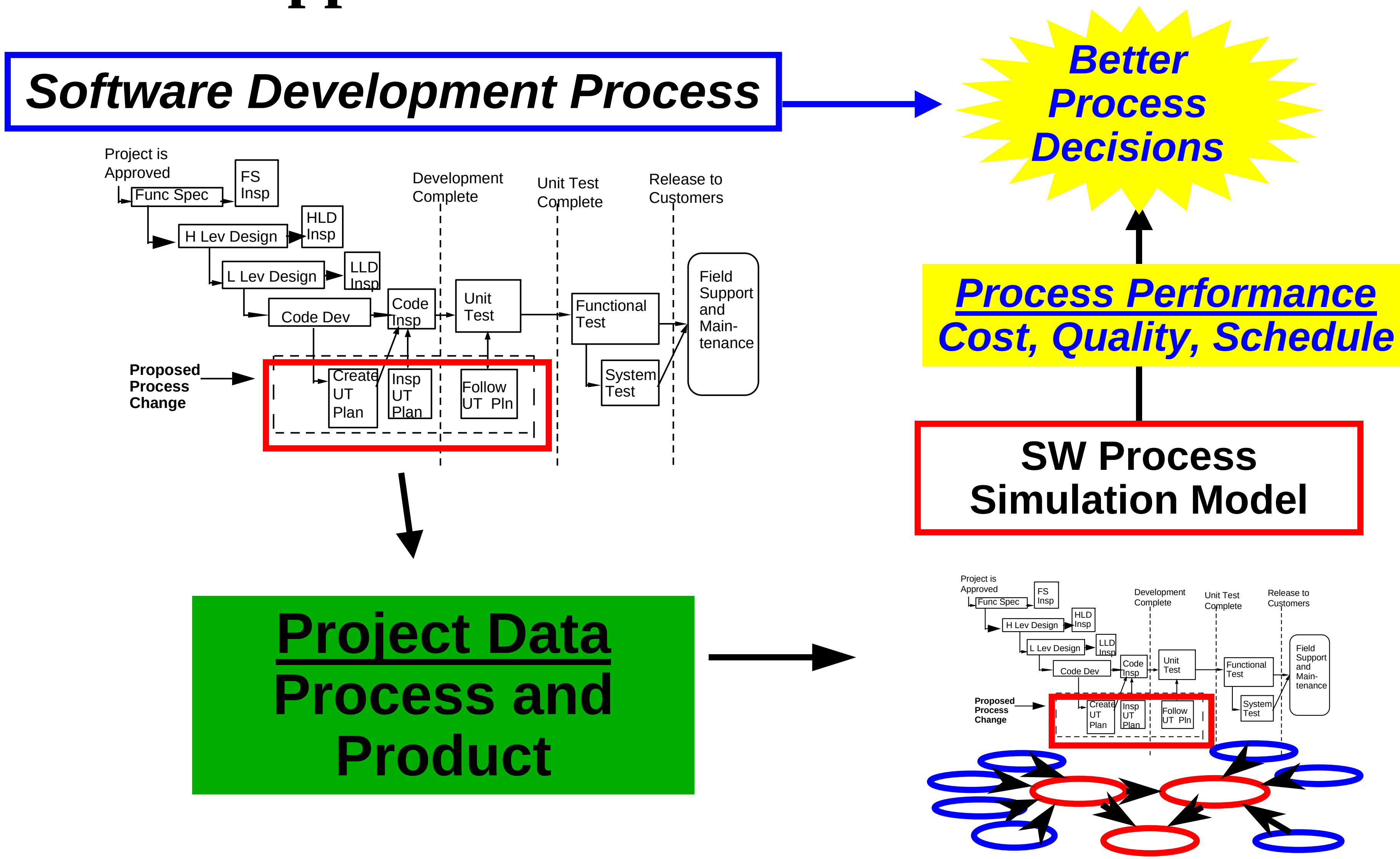
Importance/Benefits – Enduring Needs

- NASA Project Level
  - Software Quality Assurance Strategy Evaluation for NASA Projects
  - Independent Bottoms-Up NASA Project Cost Estimation
  - NASA Contractor Bid Evaluation
  - Software Assurance Replanning
  - Cost/Benefit Evaluation of new technologies and tools

Importance/Benefits – Enduring Needs

- IV&V Level
  - IV&V New Business Planning (Independent Bottoms-Up Cost Estimation for NASA Projects and for IV&V)
  - IV&V Policy Research (IV&V strategies for alternative NASA Project types)
  - IV&V Services Contract Bid Support
  - IV&V Services Replanning
  - Cost/Benefit Evaluation of new technologies and tools
  - Space Science Data Mining

General Approach



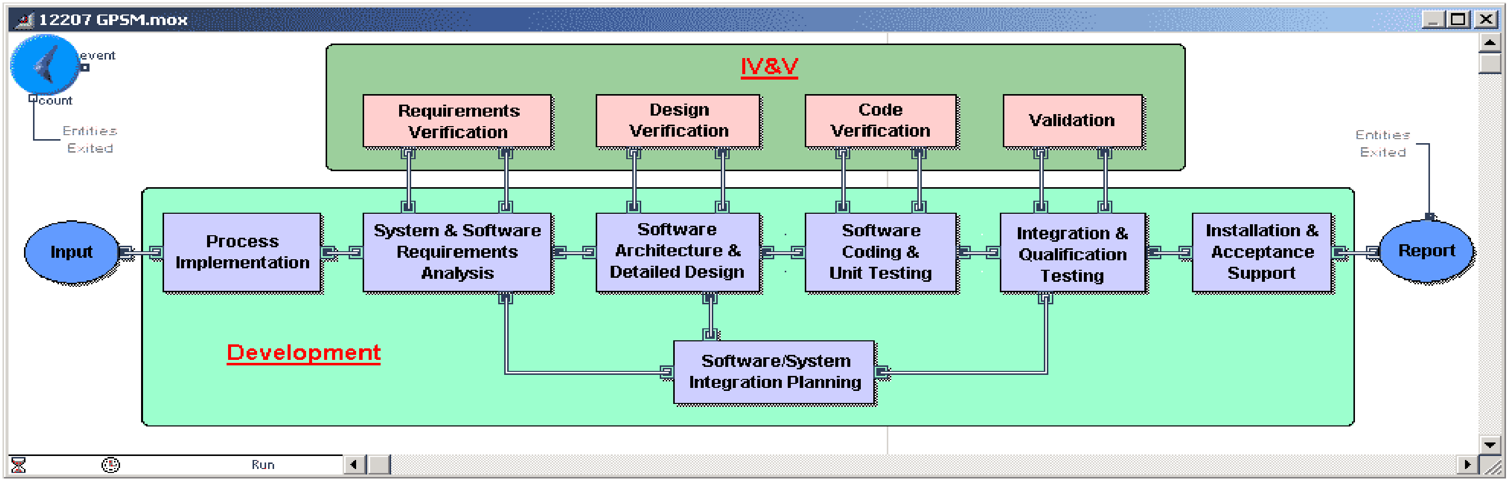
Goal

- In this paper, we assess the impact of these learned defect detectors on a “typical” large-scale NASA project in terms of overall cost, quality and schedule performance
- Goal: To determine when these learned detectors might be ***useful*** and when they might be ***useless*** by providing a business case to support the adoption of these tools.

Business Case Questions

- What is the impact of applying new tools and technologies?
- What is the economic benefit or value of the tool or technology? What is the ***Return on Investment***?
- Under what conditions does the tool or technology perform best? Under what conditions does it perform poorly?
- What performance standards does the tool need to achieve in order to have a positive performance impact on the project/organization?
- Are there alternative ways to apply the tool or technology that enable it to provide a more positive impact?

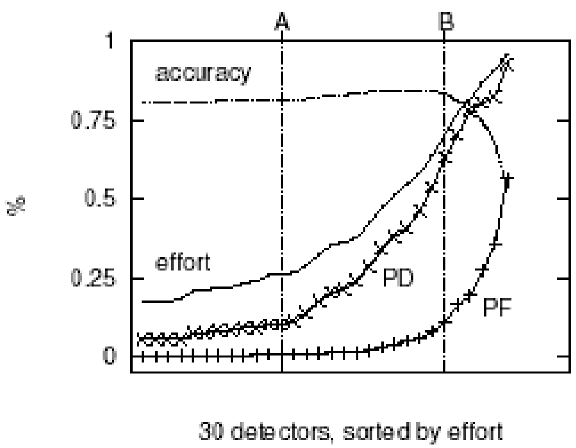
Model Overview



Description of Model

- IEEE 12207 Software Development Process (commonly used)
- Utilizes actual data from 8 large NASA projects (Size >100 KSLOC)
- 8 major life cycle phases; 86 process steps
- Includes IV&V Layer
- Alternative IV&V application configurations can be compared (ROI)

Assumptions

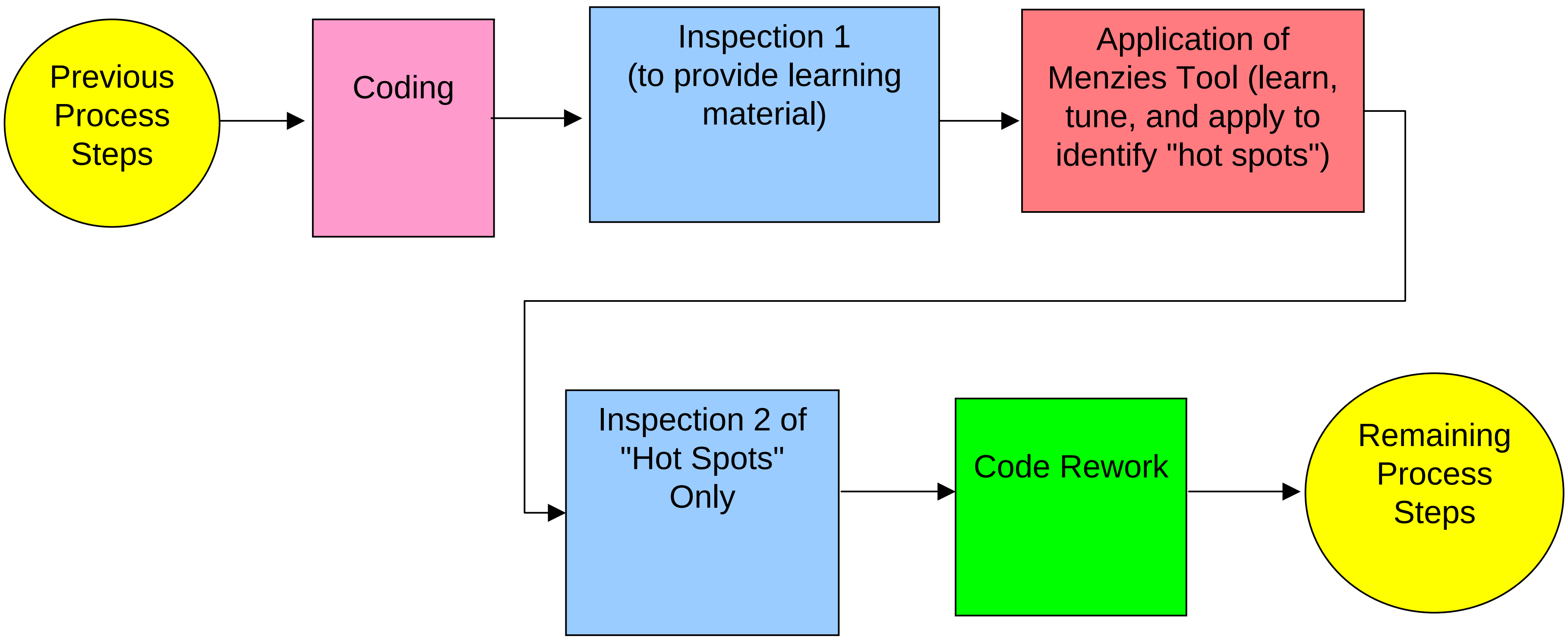


- Project Size is 100 KSLOC.
- Software process follows the IEEE 12207+IV&V model. True for many DoD and NASA projects.
- %LOC Inspected=PD+5% to 10%; and %LOC is proportional to Effort
- PF = 10%-30%.
- PD=40 to 70%.
- The PD rate assumes, in turn, that defect detectors are learned from data divided below the sub-system level.
- Standard manual inspections find 40% to 60% of the total defects.
- Perspective Based inspections find 80% to 90% of latent defects
- Defects uniformly distributed throughout code

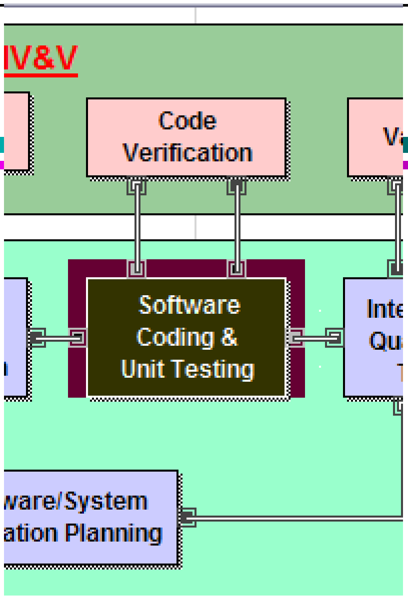
Scenario I - Applying LDD to V&V

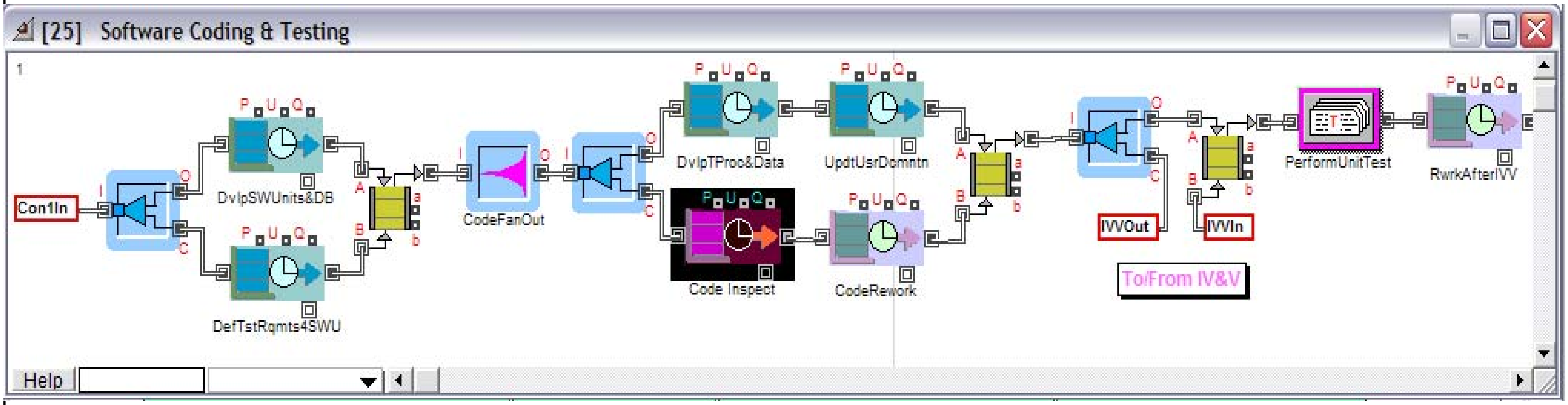
- Learned defect detectors are applied during project V&V.
  - Inspections are conducted on 11.5% of code to learn defect detectors
  - LDDs then applied to remaining code to identify high-risk portions of the system
  - Explored the impact of using higher PD combined with higher PF
  - Explored the impact of using regular inspections(weak training set) vs Perspective Based inspections (strong training set) for LDDs.

Changes to the Process



Changes to the Model





Scenario I - Results Summary

- Model recommendations for specific scenarios
- M^3 Rule (Martha, Menzies, McGill Rule) - Learned Defect Detector Rule:

PD_V&V* %Code_Inspected*95%<= PDL* PDI_TS

Where:

PD_V&V – Probability of detection of V&V inspections

%Code_Inspected - % of code inspected during V&V

PDL – Probability of Detection for LDDs

PDI_TS – Probability detection of Training Set inspections

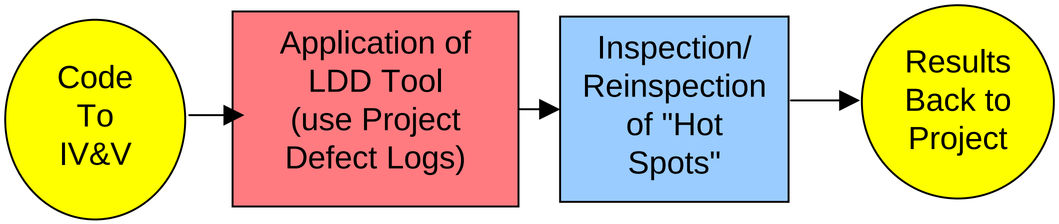
Scenario I - Results Summary

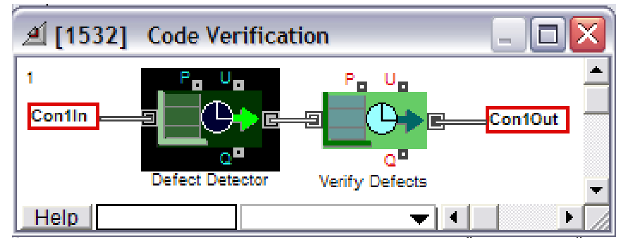
- LDDs are ***Useful*** (Significant benefits) in a V&V setting when:
  - 53% or less of the code is inspected during V&V (manned vs unmanned missions) using regular inspections and LDD PD =50%
  - Using high PD mode and Perspective based inspections
  - Project inspections are poor
- Applying LDDs to V&V are ***Useless*** when:
  - Project inspections are good or high quality
  - More than 53% of the code is inspected by V&V (typical for manned missions)

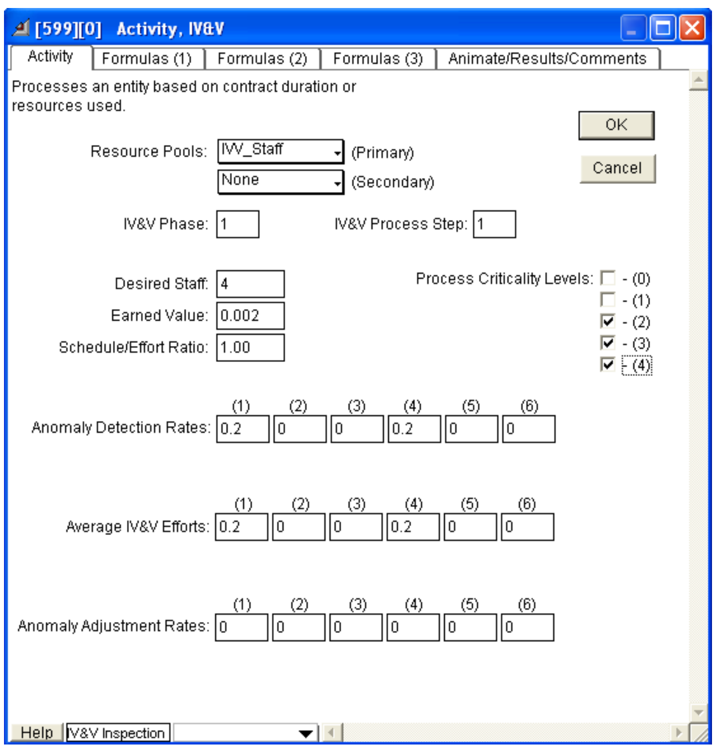
Scenario II - Applying LDD to IV&V

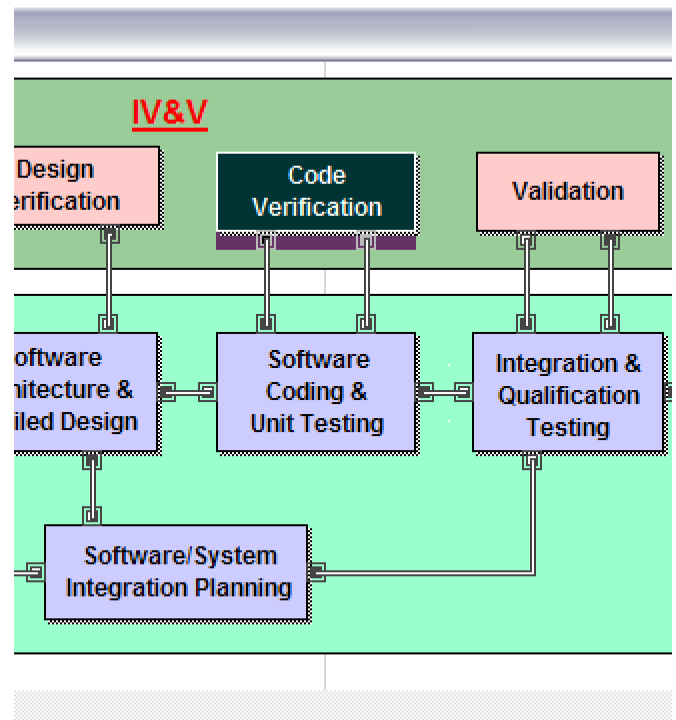
- Learned Defect Detectors (LDD) applied to IV&V (Shedding light on blind spots)
  - Project generated training sets (regular inspections)
  - Investigated the Impact of applying LDD to different project types (varied amount of code that is reinspected (100%-25%))
  - Varied the effectiveness of reinspection (2%-10%)

Changes to the Process – IV&V









Scenario II - Results

- Clear recommendations for specific scenarios
- Results (Excellent Application):
  - Low Risk = 1.2 PM with no defects detected
  - Improves quality if any defects are found (detection capability > 0)
  - Receive added assurance even if detection capability is 0
  - For Manned Missions, (100% reinspection), break-even on total project effort if IV&V reinspection effectiveness = 2%
  - Significantly improves cost, quality and schedule if reinspection effectiveness is >= 5%

Scenario II - Results

- Significant up side potential when LDDs are used to identify high risk portions of the code that were not previously inspected during project level V&V (unmanned missions).
- At 50% code inspected by V&V, 4%-7.5% reduction in delivered defects
- At 25% code inspected during V&V, reductions in delivered defects range from 15%-24%. Effort savings range from 18 PMs to 29 PMs.

Conclusions – Mission Accomplished

- Learned Defect Detectors ***are useful*** when they ***increase*** the overall detection capability of the Coding phase.
- M^3 Rule (Martha, Menzies, McGill Rule) –
  PD_V&V* %Code_Inspected*95%<= PDL* PDI_TS
- This occurs when:
  - Less than 53% of code is inspected during V&V or V&V has week inspections
  - Used as IV&V technique identifying blind spots and augmenting regular high-quality V&V
  - V&V has weak inspections

Conclusions – Mission Accomplished

- Learned Defect Detectors ***are useless*** when they ***decrease*** the overall detection capability of the Coding phase.
- This occurs when:
  - Used to frivolously cut costs by replacing high quality code inspections.

Conclusions – Broader Impacts

- Identify the conditions under which application of a new technology **would be** beneficial and when applying this technology **would not be** beneficial.
- We can define performance benchmarks/ criteria that a new technology needs to achieve.

Conclusions – Broader Impacts

- We can diagnose problems associated with implementing a new tool or technology and identify new ways to apply the technology to the benefit of the organization (and the vendors)
- Finally, we can do all this ***before*** the technology is purchased or applied and therefore can save scarce resources available for process improvement.

Conclusions – Broader Impacts

- Synergistic research of multiple projects sponsored by NASA
- Process Simulation enabled us to do a detailed analysis of a new tool that NASA has been investing in
- ***More data please, it can be used to NASA's advantage!***

The End